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Procedia Computer Science

Volume 51, 2015, Pages 1603–1612

ICCS 2015 International Conference On Computational Science

Procedia Computer Science

Influence of the External Environment Behaviour on the Banking System Stability

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Abstract

There are plenty of researches dedicated to financial system stability, which takes significant place in prevention of financial crisis and its consequences. However banking system and external environment interaction and customers behaviour influence on the banking system stability are poorly studied. Current paper propose agent-based model of banking system and its external environment. We show how customers behaviour characteristics affect a banking system stability. Optimal interval for total environmental funds towards banking system wealthy is performed.

Keywords: banking system, modelling, stability, external environment, customers

1 Introduction

Financial systems fragility can lead to crises that adversely affect quality of life and cause panic. That changes in turn aggravate the crises [9]. A lot of papers are devoted to investigating fragility reasons and try to find a way to optimize financial systems policy. The main trends of these studies are showed below (Fig. 1).

The first approach concerns the managing single bank policy based on balance sheet information analysis. As a single institute is an inner element of the financial system, we can think that the optimization of each network's institute policy would lead us to whole financial system robustness. However, optimization for itself can make the system more fragile [9]. At the same time research of the balance sheet requirements and single bank policy influence is an actual problem which captures many researchers' attention [3, 11]. In 1979 the CAMELS rating system was implemented, in 1988 the Basel Accord introduced minimum capital requirement, in 90s the Kromonov method of the financial institute reliability assessment was suggested. These three systems use balance sheet information for assumption of bank robustness. In [3, 11] bank portfolios influence is also considered.

Selection and peer-review under responsibility of the Scientific Programme Committee of ICCS 2015

doi:10.1016/j.procs.2015.05.292

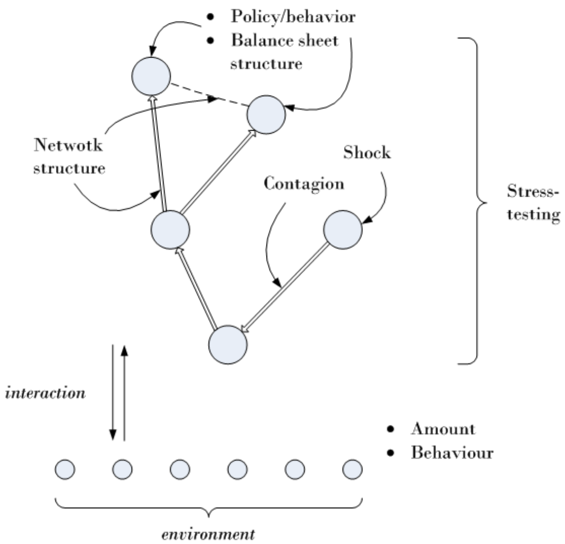


Figure 1: Areas of a banking system stability research. Influence of external environment, which can be presented with some processes or bank customers, depends on customers' amount and their behaviour. Big circles correspond to banking system agents, arrows correspond to shock contagion direction. Network structure implies edges existence or absence and properties connected with it.

The second approach is to choose features that occur at bankruptcy and classify, if the bank looks like close to bankruptcy or not [8, 12, 15]. Gordini [8] used info from database containing bank accounts records for one, two, and three years before bankruptcy. Division to bankrupt and non-bankrupt cases was done for the same year. Trabelsi [15] also used database info and examined the impact of cut-off points choosing and sampling procedures. Jeong [12] used a set of balance sheet samples for bankrupt and non-bankrupt organizations and applied the general additive model to select useful and less redundant variables for classification. All of the papers described above compared different classifiers and their combinations to predict bankruptcy with chosen features.

An influence of the network structure is explored by the third approach, which illustrate how concentration, complexity, clustering, connectivity and other features of the network structure description affect the network fragility. They do the shock propagation and introduce measure of contagion (Contagion Index, for example [6]) to find more robust structure. Georg [7] showed that centralised banking system is more stable in crises than a random one, whereas in non-crises time structure does not matter. Nier [13] also showed that more capitalised systems are more resilient to contagion. Increase in the degree of connectivity implies absorbing shocks, whereas when it takes small values the opposite effect occurs. In modelling authors either emulate an existing banking system or use random graphs of Erdos-Renyi [5] or Barabasi-Albert [1].

Stress-testing concerns to all network components described above: micro stress tests for individual portfolios and macro stress tests for financial institute groups. Stress test purpose is to detect vulnerabilities and to provide management scenarios for crisis situations [2].

The last approach for financial system stability studying concerns external environment. Environment allows banks to get profit and can bring troubles with their behaviour. Therefore the banking system has to satisfy its environment needs and to be resistant to its behaviour changing not to fail. It means that the policy should be as flexible as necessary to continue getting profit (or not to loose) when situation has changed. Robertson [14] offers agent-based toolkit for strategic-management. His model contains turbulent environment, where customers have a satisfaction level. The satisfaction is defined as the Euclid distance between a customer and its bank in the strategy space. Each bank and customer strategy is performed by n-component vector: a component for each space dimension. Customers try to minimize their satisfaction level and change the bank if it's not optimal. Turbulence mean that customers change their policy in a random way therefore the bank should tune their policy according to it.

Current research is close to the last fifth direction because of importance of customer-bank interaction in banking system fragility prediction and because this question is poorly studied. We introduce banking system model with external environment. Banks have their "save" strategy of behaviour. The "safety" concept is defined in the work (it was not been defined in the above papers). The external environment is presented with customers, who interact with the banking system. It is shown how the current model stability depends on the customers behaviour parameters.

Structure of the paper is the following: in the section 2 we describe our model arrangement; in the 3 one we present our experiment results. Finally, there is conclusion and future work description in the section 4.

2 Model description

Our model is a multi-agent system, consisting of a banking network, where agent is a bank, and external environment, where agent is a customer. Every bank has a strategy of behaviour which prohibits insecure deals and promote borrowing action when bank fails. That borrowing action involves other banks to improve bankrupt's status. If it doesn't help, bankrupt is excluded from the system.

Banking network is represented as a multi-graph where nodes are associated with banks and edges correspond to interbank lending. Customers interact with banks and stimulates interbank activity. As banks do not want to lose customers, they try to satisfy customers' requests even in loss of funds. Therefore banks interact with other banks to provide "safety" of customer-bank deal. "Safety" concept will be introduced further in the paper (section 2.2.2).

2.1 Network structure

As in papers [13, 4, 10] our banking system is initialised as the random Erdos-Renyi graph [5], which is initialized with input parameters: N for number of nodes, p for probability of edge existence. Each edge contents information about model time when it was created, investment size, interest rate, index of bank it was assigned to and term of repayment.

Multi-edges are obtained on the next steps of modelling, when two interconnected banks creates next link with other investment size, or date of creation, or something else.

2.2 Agents: structure and behaviour

2.2.1 Structure

Each network agent condition is determined by its balance sheet (Fig. 2). Also there is *OperatingCost* (OC) value which subtract available funds and performs casual consumption for each iteration.

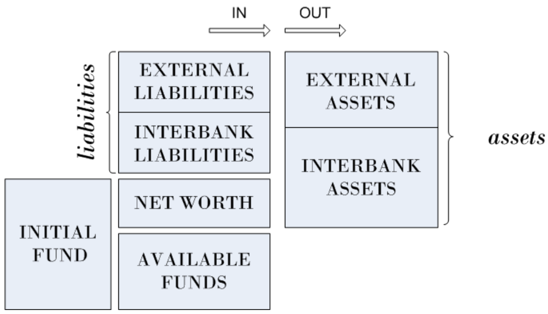


Figure 2: Balance sheet structure for each agent. Columns' height ratios correspond to ratios of components' size

Assets are the funds agent invests somewhere for getting profit in the future. Liabilities provide investments which do not carry active profit but bring real money for usage. The more liabilities the more available funds. The more assets — the more net worth is. The both assets and liabilities are divided into two groups: external and interbank. External assets and liabilities correspond to relations between the bank and a customer. We will use the following notation for these balance sheet components:

NW — the net worth,
AF — available funds,
A — all banks' assets,
EA — external assets,
IA — interbank assets,
L — all banks' liabilities,
EL — external liabilities,
IL — interbank liabilities,
OC — operating costs.

Then by definition the next relations are hold:

$$A = EA + IA; \tag{1}$$
$$L = EL + IL; \tag{2}$$
$$NW = A - L; \tag{3}$$
$$AF = IF - A + L; \tag{4}$$

where IF is some initial fund, which is assigned to each bank after formation.

We have analysed a number of year reports of Russian banks ("OTP"[1], "Rusfinance"[2], "VTB24"[3], "Svyaz-bank"[4], "Sberbank"[5]) and got the next average relations for their balance

[1] http://www.otpbank.ru/f/about/akcyy/last_year_reports/annual_report_2013g.pdf (in Russian)
[2] http://www.rusfinancebank.ru/file/doc/msfo/RFB_IFRS_FS_13_rus.pdf (in Russian)
[3] http://www.vtb24.ru/about/info/results/Documents/vtb24_accounting_report_2012.pdf (in Russian)
[4] http://www.sviaz-bank.ru/files/images/2013.pdf (in Russian)
[5] http://www.sberbank.ru/common/img/uploaded/files/pdf/yrep/Annual_report_ru_2013.pdf (in Russian)

sheet parameters:

$$EA = 0.8 \cdot A; \tag{5}$$
$$L = 0.86 \cdot A; \tag{6}$$
$$EL = 0.59 \cdot L; \tag{7}$$
$$NW = 0.13 \cdot A; \tag{8}$$
$$OC = 2.08 \cdot NW. \tag{9}$$

Since these relations can not be achieved for all network agents simultaneously and in view of initialization as the Erdos-Renyi random graph we used the next consequence of relations (M — incidence matrix, $m_{i,j}$ — size of funds which were sent from i-th to j-th bank; edge weight is in $[0; p]$ segment).

$$IA = \sum_{i=1}^{N} m_{i,j} \cdot 1000; \tag{10}$$
$$EA = 4 \cdot IA; \tag{11}$$
$$A = 5 \cdot IA; \tag{12}$$
$$L = 0.86 \cdot A; \tag{13}$$
$$IL = \sum_{j=1}^{N} m_{i,j} \cdot 1000; \tag{14}$$
$$EL = L - IL; \tag{15}$$
$$OC = 2.08 \cdot NW; \tag{16}$$

Since the first step of the model initialization is interbank lending creation, IA and IL — are the first balance sheet components we can get. Formulae (11) and (12) follow from (5) and (1). Finally, formula (15) follows from (2). As far as interbank assets can be zero, liabilities may be also equal to zero. In this case we assign zero to external liabilities, and use definition for liabilities assignment.

As $m_{i,j} \in [0; p] \Rightarrow EA = 4 \cdot 1000 \cdot \sum m_{i,j} \Rightarrow EA \in [0; 4000 \cdot p \cdot N]$. Therefore we defined the desirable amount of external assets. Number of customers per bank then depends only on the loan size.

2.2.2 Agent behaviour

Each agent in the banking system can perform the following actions:

1) get profit (get its assets back with percentage which date of repayment corresponds to current time in the model),

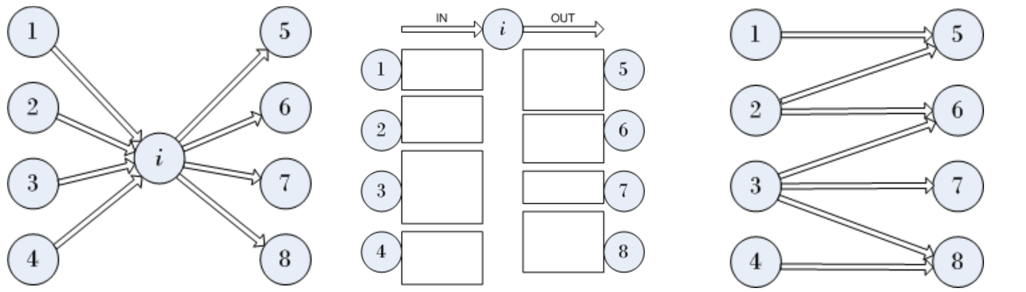
2) pay liabilities (return liabilities with percentage);

3) pay operating costs;

4) satisfy customer request;

5) satisfy other bank request;

6) request other banks for loans or deposits to provide customers requests or to improve the situation when the liquidity is lost;



(a) The example of interactions before bankrupt elimination

(b) Relative investment sizes before bankrupt elimination

(c) The corresponding interactions after bankrupt elimination

Figure 3: The bankrupt elimination scheme

7) eliminate bankrupt agent from the system and clearing the balance with minimizing the connected banks' losses.

We say the bank is liquid if its net worth and available funds are not-negative. Action is "safety" then and only then when it do not lead to the loss of liquidity. If customer or other bank request is not "safety" it will not be satisfied.

The two latter points implementation we will discuss in more detail.

Borrowing from the network As was mentioned above the bank is liquid while its net worth and available funds are not negative. We also used the more wide liquidity notion which takes into account instant, current and long-term liquidity coefficients which are used by Russian central bank[6]. If the bank has lost its liquidity, it tries to rise up assets or liabilities depending on reason of liquidity loss (namely if the net worth is negative then rising up assets, otherwise — liabilities). We know the size of the maximum available loan and deposit for each agent. So one can summarize the maximum available loan or deposit for the whole network. Also the necessary fund size to improve the bankrupt situation is known. Rising assets or liabilities of bankrupt is accompanied with creating links and is continued while the bank is not liquid. If the network does not contain the necessary fund amount, the bankrupt is eliminated from the network as described in paragraph below.

When a customer's request can lead to bank's liquidity loss then the similar situation occurs. If the network does not contain enough funds, then customer's request is ignored. Otherwise, an additional interaction between the system agents is initiated.

The bankrupt eliminating When the bank has lost its liquidity and there is not enough funds to rise it up, bankrupt is eliminated from the network. The figure 3a reflects bankrupt and its neighbour interactions before elimination. All interbank assets and liabilities are sorted for the date of repayment and assigned as displayed in the figure 3c. Links repartition occurs until the both lists (asset list and liability list) are not empty.

If the bankruptcy was caused by the negative net worth then summarized liabilities quantity is more than the similar for assets. Therefore residual liabilities will not be considered. Thus, the network agents lose funds and disrupt the network stability. If the negative available funds

[6] `http://base.garant.ru/12127405/` (in Russian)

were a reason of bankruptcy, assets remain unaccounted. That assets are added to other banks' available funds and settle there. It does not deteriorate neither the single bank condition nor the whole network.

2.3 External environment

Customers of the banks are present the external environment. This is the force that provides an opportunity of getting profit for the banking system. At the same time their behaviour can instigate interbank activity and losses.

Customers do not have restrictions on their account capacity. On each iteration each customer randomly choose a bank and asks for loan or for request. Choosing of the request kind occurs randomly. Loan probability is equals to 0.62 because of relations in formula (5–7).

3 Experiments

3.1 Feature isolation

As edges contribute shock contagion we created banking system without initial interbank borrowings (edges). Thus, interbank activity impact on systemic stability is minimized and other features influence can be explored more accurately. According to each bank policy edges will appear when the liquidity is lost or if an agent can not provide a customer's request, but whole network can.

Number of banks was 25. Erdos-Renyi probability was 0. Number of customers was varied from 100 to 2000 with step of 100, and in several experiments it was 3000, 5000, and 8000 customers. The loan request size stayed constant. We took loan frequency as 62% of all requests to ensure the equations 5 and 7.

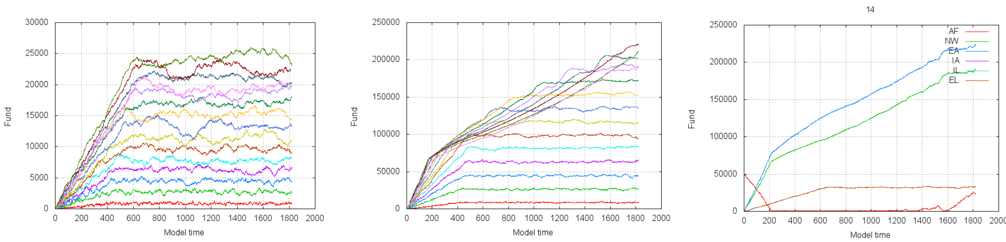
It was empirically observed that increase of the request size negatively affects system stability. When the customers' request size was 26, there were no bankrupts and no interbank links were created (because interaction was quite impossible in the beginning and became not useful, when banks already could allow themselves interbank borrowing). At the same time, after rising the request size upto 100, number of bankrupts become 25 during the 589 "days", and after rising request upto 1000 time of life for 25 banks decreases to 110 "days" (fig. 5).

Thus, one can clearly see that banking system stability depends on the ratio of available funds to the customers request. Figure 6 reflects this result. We took $AF = 2500 \cdot size$, where $size$ is customer's request size. Number of bankrupts we got was quiet similar for launches with 20, 40, 60, 80, 100 size of request: about 4 bankrupts for 600 "days" of modelling.

In fact, number of customers does not matter in this experiment set configuration because of zero operating costs. In the case of non-zero initial probability p we get two more parameters of influence: operating costs and number of customers. Their ratios significance is described below.

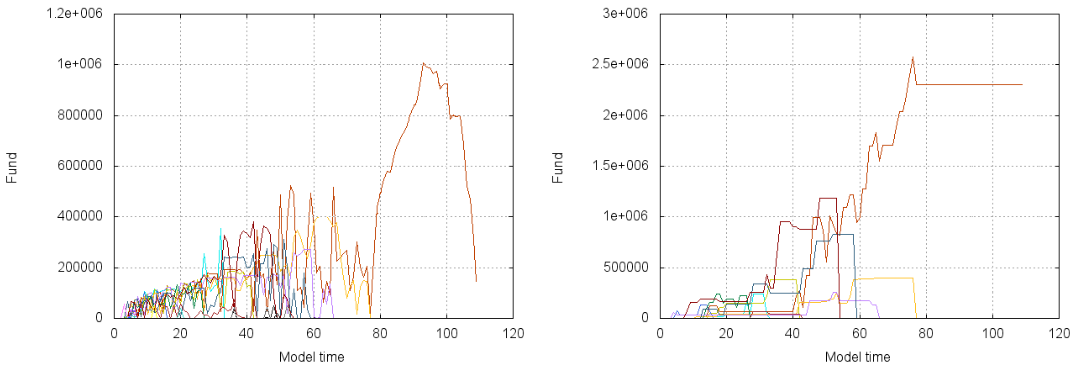
3.2 Non-zero initial probability

When initial probability do not equals zero, each iteration accompanied with subtracting operating costs from available funds. Thus, for each bank its operating costs should be less than profit. Thereby on the one hand number of customers should be not very small to provide necessary profit, and on the other hand it should not be too enormous not to be destructive. Presently we are interested in both: number of customers and their request size relation.



(a) 100 customers (b) 1000 customers (c) balance sheet components changing for the single bank

Figure 4: Net worth changing in launch with no initial interbank borrowing, size of request is 26. The figure 4a shows the net worth rises until some treshold, which is different for each bank. After it the net worth value is stabilized. This is caused by loss of net worth in the very beginning, so many customers requested can't be satisfied. When number of customers rises, stabilisation becomes later and maximal net worth value is higher. At the same time speed of net worth increasing fails for banks had better rate in the beginning. This is due to available funds come close to zero therefore request for loan have to be rejected (see in detail the fig. 4c).



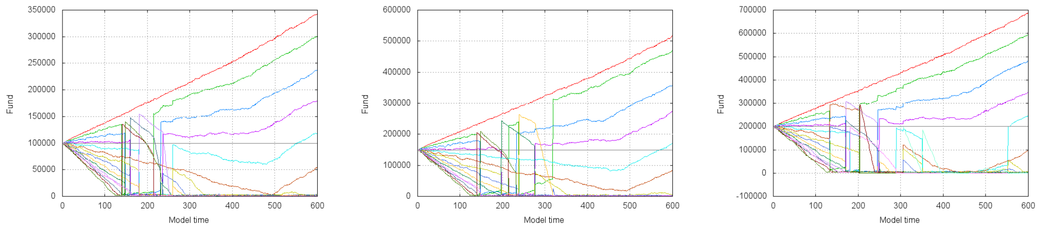
(a) Net worth changing dynamics (b) Interbank liabilities changing dynamics

Figure 5: Launch with 1800 customers and request size 1000. Number of bankrupts: 25 for 110 "days"

We have seen that there is no matter of number of customers and request size interrelation. Summarized funds of all customers for each iteration has value. Therefore we explore ratio of this summarised value to operating costs.

The experiment below is also launched for a network with 25 nodes and probability $p = 0.1287$ — this probability is chosen as a treshold for 25-node graph to be connected. Initial size for available funds is assigned with $1500 \cdot OC$, as it give a little time for stabilizing. When the constant is less then 1500, the very beginning profit is not enough because of initial terms of repayment. Number of customers is constant and equalled to 180. We vary size of customers' request to get range, which is suitable for current model parameters.

Figure 7 displays experiment results. Set of experiments showed that according to the request size banking system has stable or not number of bankrupts. Thus request size axis can



(a) Size of request is 40, initial available funds are 100 thousand

(b) Size of request is 60, initial available funds are 150 thousand

(c) Size of request is 80, initial available funds are 200 thousand

Figure 6: Available fund dynamics for the case that $AF = 2500 \cdot size$. Each line for each bank in the system.

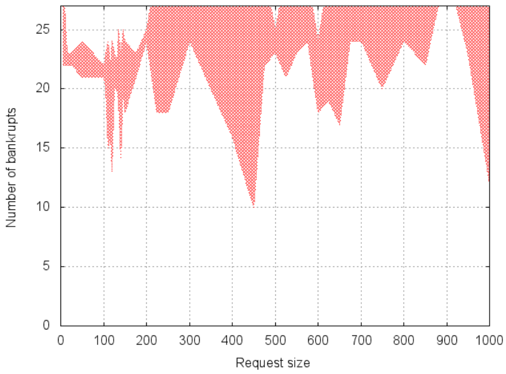


Figure 7: Number of bankrupts intervals according to size of request. Number of customers is 180. Number of bankrupts is quiet similar when size of request is 50–200, that is 9000–36000 summarized environmental funds.

be divided for zones where number of bankrupts is quite similar or it fluctuate from very good to unusable.

In accordance with this the range from 9000 to 36000 units for all customers in system provides the most stable number of bankrupts (60–75% for 600 iterations). When funds for all customers are less than 900 or more than 40000 number of bankrupts rises over 90%.

4 Conclusion and future work

In this paper we have proposed the banking system model with external environment represented with customers. The experiments with banking system having no initial links let us isolate interbank activity influence and explore environmental influence more accurately. It let us show that systemic stability can be broken not so with number of customers rising as with rising the request size. Also it is shown that unevenness of customers' bank choices can destabilize the system with regular initial parametrization for all its agents.

We show how the number of customers and their request characteristics affect the banking system stability. Optimal interval for total environmental funds towards banking system wealthy is evaluated. This results can be improved with varying influence of other environment characteristics. We are to enrich customers' behaviour strategies and explore how a single bank default depends on its interaction with external environment.

5 Acknowledgements

This paper is supported by Russian Scientific Foundation, grant #14–21–00137 "Supercomputer simulation of critical phenomena in complex social systems". The research is done in Advanced Computing Lab (ITMO University), which is opened in frame of 220 Decree of Russian Government, contract #11.G34.31.0019

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